6 BORDEV user manual

BORDEV is a modular, menu-driven computer program developed to solve problems in the design, operation, and evaluation of sloping border irrigation systems. You start the module BORDEV by selecting it in the SURDEV package. The installation procedure of this package was discussed in Chapter 4, Section 1.

6.1 Menu structure

There are six main menu items, five of which have sub-menus that you can select by moving the highlight with the arrow keys and pressing [Enter], or by typing the red (bold) character. Table 6.1 shows the structure of the main menu and its first layer of sub-menus.

6.1.1 Sub-menu files

The sub-menu *Files* gives you two options: *Load* and *View/Print*. With *Load,* you can select an existing file and continue with the calculations. With *View/Print* you can select an existing file, the contents of which will subsequently be displayed on the screen. Pressing [F5] gives you the option of sending the contents of this file to a printer, a text file, or a spreadsheet file. For more information on these topics, see Chapter 4, Section 4.3.

6.1.2 Sub-menu operation

In the sub-menu *Operation*, you can select the appropriate system operation mode. If you select *Fixed flow* it means that a constant inlet flow rate will be used to irrigate the borders during the entire application time. Selecting *Cutback flow* means that, at the end of advance, the inflow is reduced for the remainder of the application time. Selecting *Tailwater reuse* refers to a border

Table 6.1 Bordev menu structure

Files	**O**peration	**U**nits	**I**nfiltration	**C**alculation	**Q**uit
Load	**F**ixed flow	**F**low rate	**M**odified SCS families	**1.** Flow rate	
View/Print	**C**utback flow	**L**ength	**K**ostiakov-Lewis equation	**2.** Length	
	Tailwater reuse	**D**epth		**3.** Cutoff time	
		Time		**4.** Min. Depth	

irrigation system with a runoff reuse arrangement. Because BORDEV only simulates the flow in one border, the reuse component is not integrated in the required flow rate of another border. The default operation mode is *Fixed flow*.

6.1.3 Sub-menu units

The sub-menu *Units* is where you can choose pre-determined units for flow rate, length, depth and time. The following units are available:

- Flow rate: Litres per second, US gallons per minute, cubic metres per minute, or cubic feet per minute.
- Length: Metres or feet, used for border length and width.
- Depth: Millimetres or inches, used for the various supplied and infiltrated depths.
- Time: Minutes or hours, used not only for advance, cutoff, depletion and recession time, but also for the infiltration equations.

The selected units are maintained throughout the program and are also saved with the file. When the program is started, default units are: litres per second for flow rate; metres for border dimensions; millimetres for infiltrated depths; and minutes for time.

6.1.4 Sub-menu infiltration

In the sub-menu *Infiltration*, you can select one of two different infiltration input modes. Both modes are based on the infiltration characteristics of a soil as described by the Kostiakov-Lewis equation (Equation 3.4):

$$D_i = kT^A + f_0T$$

where D_i is the cumulative infiltration after an infiltration opportunity time T, k is the infiltration constant, A is the infiltration exponent, and f_0 is the basic infiltration rate. In BORDEV, you can enter the soil infiltration characteristics A, k, and f_0 directly or indirectly by using the modified SCS families. For more background information on this subject, see Chapter 3, Section 1.1. The default infiltration input mode is the *Modified SCS families*.

6.1.5 Sub-menu calculation

Before actual data can be entered and calculations can be made, you have to select one of the four modes in the sub-menu *Calculation* (Table 6.1). What the first three modes have in common is that the calculated minimum infiltrated

depth at the downstream end of the border always equals the required depth. In other words, no under-irrigation will occur at the downstream end, whereas over-irrigation always occurs in the upstream part. When to use the various modes is summarised below.

Calculation Mode 1: Flow rate
Calculation Mode 1 is primarily for design purposes, when you know the border dimensions and want to know the approximate flow rate that is needed to achieve a reasonable performance. The program will also give you the required cutoff time and the primary performance indicators as well as various depth and time parameters.

For the operation modes *Fixed flow* and *Tailwater reuse*, BORDEV calculates the flow rate in such a way that the application efficiency is approximately maximised. For the operation mode *Cutback flow,* the flow rate is determined so that the user-specified advance ratio is achieved. Although the result obtained in this mode is usually close to these targets, it is nevertheless required that you continue running in Modes 3 and/or 4, because in most cases small refinements are still possible.

Calculation Mode 2: Dimensions
Calculation Mode 2 is the reverse of Calculation Mode 1: the flow rate is now known and you want to know the approximate border dimensions that are needed to achieve a reasonable performance. The program will also give you the required cutoff time and the primary performance indicators as well as various depth and time parameters. In this Mode, the user is required to give the length/width ratio a figure. The maximum application efficiency is approximate and to get a final result you must continue in Modes 3 and/or 4.

Calculation Mode 3: Cutoff time
Calculation Mode 3 is one of the two main modes of BORDEV. It will be the one most frequently used and will also be the starting mode for the experienced user. Here, both the flow rate and border dimensions are input. The required cutoff time is the resulting design variable, while the application efficiency and other secondary output are also given. Note, in this mode, the advance ratio is an output, because it is not possible to fix advance ratio, border dimensions and flow rate and, at the same time, satisfy the requirement that the minimum infiltrated depth equals the required depth.

Calculation Mode 4: Minimum Depth
This is the other main mode of the program. The cutoff time, border dimensions and flow rate are specified as input. Thus, all design variables are input, which means that the required depth at the end of the field will usually not be achieved (ie, that under and/or over-irrigation can occur). The minimum infiltrated depth that occurs at the far end of the field is the main item that deter-

mines whether there is under or over-irrigation. It is therefore given as first output, together with the primary performance indicators: application efficiency, storage efficiency and distribution uniformity. This mode is most suitable for performance evaluation of an existing border irrigation system and for testing the performance sensitivity to a change in the field parameters.

6.2 Input windows

After you have selected a calculation mode, BORDEV will display the input screen for data entry: *Field Parameters* and *Input Decision Variables.* The input data to be provided in the two windows are summarised in Table 6.2.

6.2.1 Field parameters

Infiltration

Upon selection of the *Modified SCS families* type of infiltration data, BORDEV will use it for borders, as was discussed in Chapter 3, Section 1.1. One of seventeen families can be chosen. If a wrong number is typed, an error message with a list of acceptable numbers is shown. To select a particular family, you can use the Help screen by pressing [F1] while the cursor is on the family number. A screen with the possible numbers will pop up from which you can make your selection (Figure 6.1).

Table 6.2 Input variables for the Bordev calculation modes

	Fixed flow				Cutback flow				Tailwater reuse			
	Mode				Mode				Mode			
Item	1	2	3	4	1	2	3	4	1	2	3	4
Field Parameters												
Infiltration	o	o	o	o	o	o	o	o	o	o	o	o
Required depth	o	o	o	o	o	o	o	o	o	o	o	o
Flow resist.	o	o	o	o	o	o	o	o	o	o	o	o
Slope	o	o	o	o	o	o	o	o	o	o	o	o
Input Decision Variables												
Inlet flow rate		o	o	o		o	o	o		o	o	o
Length/width ratio		o				o				o		o
Border length	o		o	o	o		o	o	o		o	o
Border width	o		o	o	o		o	o	o		o	o
Cutoff time				o				o				
Advance ratio					o	o						
Cutback ratio					o	o	o	o				
Tailwater recovery ratio									o	o	o	o

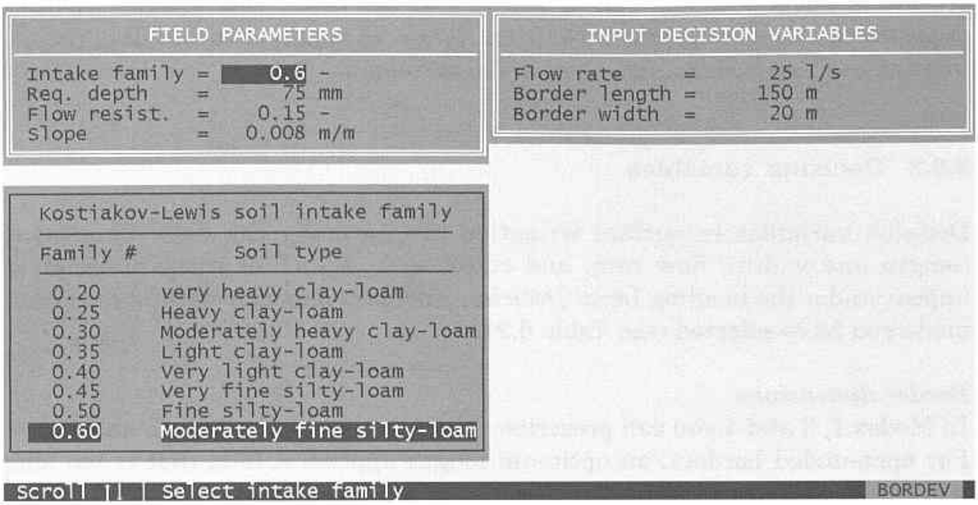

Figure 6.1 Intake family numbers to choose from

When you select a family number, the program uses the corresponding values A, k, and f_0 of the Kostiakov-Lewis equation (see Table 3.3). You can check this by selecting a family number, making a run, going back to the sub-module *Infiltration*, selecting the Kostiakov-Lewis equation mode, and returning to the input window again where you see the infiltration parameter values.

The values of the intake parameters A, k, and f_0 can be specified directly by selecting the *Kostiakov-Lewis equation*. Converting A, k, and f_0 values to other than the default units can be done as follows: go back to the *Units* menu, change time and depth units, and return to the input window again where the new values with their units will appear.

Required depth
The depth to be infiltrated at the end of the border is the second input in the *Field Parameters* window. This target is determined outside BORDEV, as was explained in Chapter 3, Section 1.3.

Flow resistance
The value of Manning's roughness coefficient (n) can be specified in the *Field Parameters* window. Recommended values can be seen under the [F1] when the cursor is on the resistance value in the input screen.

Field slope
The field slope of graded borders should neither be too high, to avoid erosion, nor too low, which would result in a too slow advance. Borders are usually best suited for slopes of less than 0.5 %. They could, however, also be used for slopes of more than 4 % where sod crops are grown. On most border slopes,

erosion is not a problem, except possibly at the head, where water velocity depends on the way in which the total inflow is supplied to the field (point-inlet, type of inlet structure, head ditch, siphons).

6.2.2 Decision variables

Decision variables in surface irrigation are normally the field dimensions (length and width), flow rate, and cutoff time. Which of these parameters appear under the heading *Input Decision Variables* depends on the calculation mode you have selected (see Table 6.2).

Border dimensions
In Modes 1, 3 and 4 you can prescribe values for the border length and width. For open-ended borders, an optimum length applies. A field that is too long will result in a low performance because of a long advance time, with consequently an uneven infiltration and high deep percolation losses. On the other hand, a field that is too short would result in surface runoff that is too high. Consequently, for open-end borders, the optimum length (with all other variables given) is where the sum of deep percolation and surface runoff losses is at its minimum and hence the application efficiency is at its maximum.

Length / width ratio
In Mode 2, the length/width ratio is required to allow the program to calculate the border dimensions, based on a given flow rate.

Flow rate
In Modes 2, 3 and 4 you can assign values to the total flow rate available for the field. In BORDEV, this inflow rate is divided by the field width to obtain a unit flow rate per metre width, which is used in the numerical simulations. The flow rate should not be too low, otherwise the flow would not reach the end of the border. It should also not be too high, to avoid excessive runoff. Thus, with open-end borders, there is an optimum flow rate (similar to the optimum border length), whereby the sum of deep percolation losses and surface runoff losses is at its minimum, meaning a maximum application efficiency.

Cutoff time
In Modes 1, 2 and 3, the cutoff time is a result of the calculations. In Mode 4, a user-specified value can be given. For all three irrigation methods, cutoff is usually done some time after the end of advance, so that the required depth can infiltrate at the downstream end. When the cutoff time is substantially later than advance time, it will have a clear effect on recession, and thus on deep percolation and surface runoff losses. When cutoff is too early, the required depth at the end of the field may not be achieved.

Advance ratio
The advance ratio, defined as the ratio of advance time to cutoff time, is especially of interest in cutback operation, where it can be either input or output, depending on the purpose (Mode) of the simulation.

Cutback ratio
The cutback ratio must be specified in all calculation modes during a cutback operation. It is defined as the ratio of the reduced flow rate to the initial flow rate, such that the reduced flow is sufficient to keep the entire field length wetted as long as is necessary, while at the same time reducing the surface runoff. Because of the calculation algorithm used, cutback is assumed to be done when the water has reached the end of the field.

Tailwater reuse ratio
The tailwater reuse ratio must be specified in all calculation modes for a reuse operation. It is defined as that part of the surface runoff that is reused and applied directly to calculate the application efficiency. A ratio of 1 would be ideal but may not always be possible, particularly because of high costs of the reuse system.

6.2.3 Input ranges

Ranges have been fixed for all input variables as shown in Table 6.3 and are in metric units. If other units are chosen in the menu, the indicated ranges are converted in the program.

Table 6.3 Accepted ranges of input parameters

Input parameters	Accepted values
Field Parameters	
Intake family #	0.05 - 2.0
Infiltration coefficient, k	0.05 – 50 mm/min^A
Infiltration exponent, A	0.01 - 0.8
Infiltration constant, f_o	0.005 – 30
Required depth, D_{req}	33 - 250 mm
Flow resistance, n	0.01 - 0.40
Field slope	0.0005 - 0.05 m/m
Input Decision Variables	
Border length, L	50 - 500 m
Border width, W	1 - 200 m
Length/width ratio, L/W	1 – 30
Flow rate, Q	1 - 250 l/s
Cutback ratio	0.65 - 1.00
Advance ratio	0.1 - 0.9
Tailwater reuse ratio	0.1 - 1.0
Cutoff time, T_{co}	10 – 2000 min

Based on a large number of runs, the ranges have been fixed in a bid to avoid too many impossible combinations and corresponding error messages. For all practical purposes, the ranges of the individual parameters will be more than sufficient. If you combine extreme values of the individual parameters you may not get a result. In that case, BORDEV will flash you a message on the screen indicating how to change these values in order to get a result.

The above ranges are ignored for output results, so, no warning will be given if such an out-of-range value is subsequently used as input in another mode.

6.3 Output Windows

When you have keyed in all the data, press [F2] for the calculations and the output. The screen again shows the two input windows, but a third window has now been added, showing the results (Figure 6.2). These results are presented in various groups, separated by a blank line. The first group contains the desired variable or variables according to the calculation mode you have selected: in Mode 1 they are the flow rate and the cutoff time; in Mode 2 the border length, the border width and the cutoff time; in Mode 3 the cutoff time; and in Mode 4 the minimum infiltrated depth.

The second group contains the primary performance indicators as discussed in Chapter 3, Section 3. All the calculation modes allow the performance of an irrigation scenario to be evaluated with the application efficiency, surface runoff ratio, deep percolation ratio, distribution uniformity and uniformity coefficient; Mode 4 adds the storage efficiency. Finally, using [PgDn], you

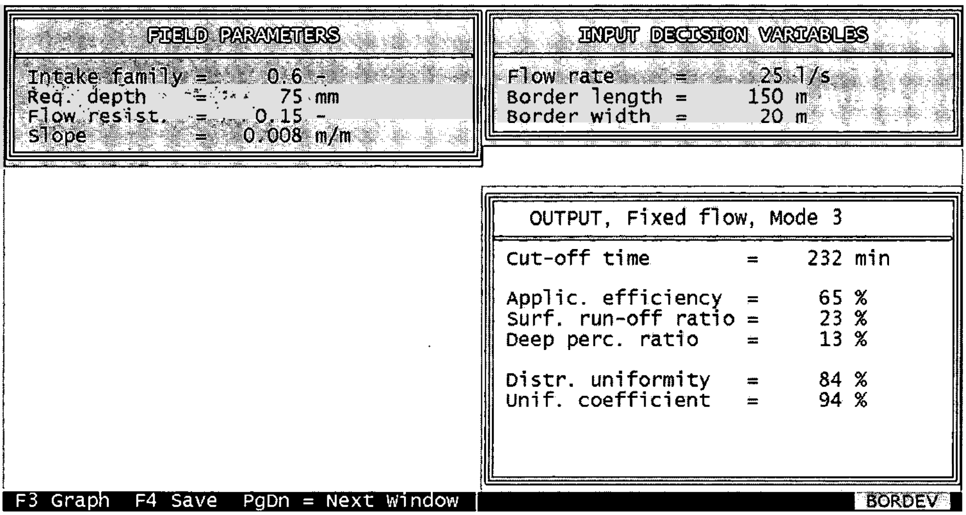

Figure 6.2 Bordev output example

obtain two groups with secondary output variables: times and depths. Outputs in all calculation modes are advance time, depletion time, recession time and intake opportunity time corresponding to the downstream point.

In all the calculation modes, BORDEV provides information on the maximum, minimum and average infiltrated amounts, together with the amount of surface runoff. In addition, Mode 4 also presents the amount of over/under-irrigation as the average amount over that part of the border that received deficit/excess irrigation. The output also includes the length of the border segment over which deficit and/or excess irrigation occurs.

The output results shown are dependent on the combination of *Operation* and *Calculation* modes. For the operation mode *Fixed flow* and *Tailwater reuse*, the output results of the various calculation modes are shown in Table 6.4 on the screen. For the operation mode *Cutback flow*, however, the cutback flow rate is added to the design variables for all calculation modes, while in Modes 3 and 4 the advance ratio is also added to this category.

Table 6.4 Output results for the Bordev calculation modes (Fixed flow system)

Output parameters	Mode 1	Mode 2	Mode 3	Mode 4
Design variables				
Border length		o		
Border width		o		
Flow rate	o			
Cutoff time	o	o	o	
Minimum infiltrated depth				o
Primary performance indicators				
Application efficiency	o	o	o	o
Surface runoff ratio	o	o	o	o
Deep percolation ratio	o	o	o	o
Storage efficiency				o
Distribution uniformity	o	o	o	o
Uniformity coefficient	o	o	o	o
Time variables				
Advance time	o	o	o	o
Depletion time	o	o	o	o
Recession time	o	o	o	o
Intake opportunity time	o	o	o	o
Infiltrated depths				
Maximum infiltrated depth	o	o	o	o
Minimum infiltrated depth	o	o	o	
Average infiltrated depth	o	o	o	o
Surface runoff	o	o	o	o
Over-irrigation				o
Under-irrigation				o
Length of over-irrigation				o
Length of under-irrigation				o

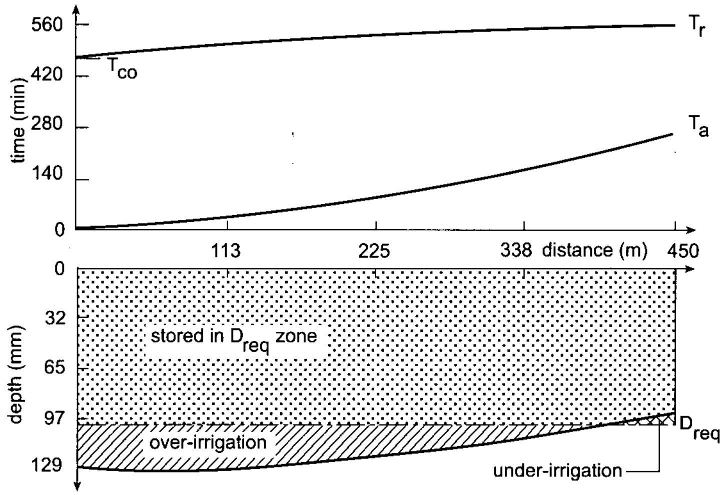

Figure 6.3 Graphical output of Bordev showing advance and recession curves and infiltration profile

By pressing the key [F3] you will see two graphs on your screen with the main results; the upper one shows advance and recession time in relation to border distance, while the lower one shows infiltrated depths along the border length. Note, that it is the recession curve that is depicted as with FURDEV, and not the cutoff time as with BASDEV. Under and over-irrigation are indicated, where applicable. This graph can be saved with [F8] or [F9]. Figure 6.3 shows the results of Run 3 of Example 1 (see Section 6.7.1 and Table 6.5).

The tabulated simulation results can be saved together with the input data, with [F4]. In a small window, the path (folder + file name) can be confirmed or changed, as described in Section 4.3.3. You can overwrite the previous file or append the current results to it. Further processing of the saved results file must be done under the *Files* menu, using *View / Print* (see Chapter 4, Section 4).

6.4 Error messages

BORDEV usually gives an output as a result of the calculations. Nevertheless, some variable and parameter combinations – mostly physically unrealistic combinations – could cause mathematical problems. When such problems are encountered, the program will terminate the calculation process and flash a message on the screen, typically containing two layers of information: the nature of the problem and suggestions on how to remedy it. Possible problems can be grouped into three categories: general advance time problems; advance time problems only related to the cutback system; and cutoff time problems.

General advance time problems
This type of problem can occur with all three operation systems if the advancing front is unable to reach the downstream end of the border. Depending on the calculation mode, BORDEV will suggest increasing the flow rate and/or decreasing the length of the border to overcome the problem.

Advance time problem with cutback system
In Calculation Modes 1 and 2, BORDEV calculates the required advance time as a function of the user-specified advance ratio and the required intake opportunity time. You can satisfy the advance time requirement by selecting an appropriate value of the flow rate in Mode 1 or that of the border length in Mode 2.

In Calculation Mode 1, the advance time associated with the maximum non-erosive flow rate can be longer than the required advance time. Here, the required advance time cannot be realised without using a flow rate that is greater than the maximum non-erosive one. This is clearly unacceptable. The only way out of this problem is to reduce the border length and/or increase the advance ratio. In addition, there are cases in which the flow rate that corresponds to the required advance time is shorter than the minimum flow rate required to advance to the downstream end of the border. When this happens, BORDEV will advise you to increase the border length and/or the advance ratio.

In Calculation Mode 2 – with some parameter and variable combinations – the required advance time could be greater than the advance time, corresponding to the maximum length to which the user-specified flow rate can advance. To overcome this difficulty, BORDEV will advise you to increase the flow rate and/or decrease the advance ratio.

Cutoff time problem
In Calculation Modes 1, 2 and 3, the cutoff time is calculated so that the minimum infiltrated depth is equal to the required depth. In Mode 4, cutoff time is an input. If the user-specified cutoff time is too short, the calculated advance time could exceed it. This is a situation that cannot be handled by BORDEV. When such a problem is encountered, the screen message will recommend decreasing the border length and/or increasing the flow rate, and/or increasing the cutoff time.

6.5 Assumptions and limitations

The BORDEV program is based on the volume balance method, which is explained in detail in Appendix B. This method simulates the propagation of the wetting front along a unit width border strip during the advance phase. The ponding, depletion and recession phases are simulated using algebraic approaches. Some implicit assumptions used in the model are:

- The bed slope is greater than zero.
- The cutoff time is always greater than the advance time. This limitation is introduced to make sure that advance and recession do not occur simultaneously, a situation that the volume balance model cannot handle.
- The cross-sectional area of flow at the inlet of the border can be described by Manning's equation.
- The water depth is limited according to the unit width to ensure steady inflow.
- The infiltration can be described by the modified Kostiakov infiltration function.
- The upper boundary of the inflow is the maximum non-erosive flow rate, which can be calculated following the approach of Hart et al. (1980). The minimum flow rate is determined on advance considerations or the flow required for adequate spread, whichever is greater (Hart et al. 1980).

More detailed assumptions involved, particularly for the depletion and recession phases, are discussed in Appendix B. Apart from these theoretical assumptions related to the algorithms used, there are a number of more practical assumptions, which could be seen as limitations. The most important are:

- The flow rate is constant during the entire application period (unless cutback operation is applied).
- The conditions at the inlet enable the water to spread evenly over the entire width of the border strip.
- The bed slope is uniform along the border, and the cross slope is zero.
- The soil is homogeneous throughout the length of run of the border.
- The roughness coefficient is constant.

Finally it is assumed that the border is free draining at the end. The program cannot calculate the advance and recession curve for closed-end conditions, or for conditions where runoff water is collected to irrigate a flat extension at the end of the border. To reduce losses, and in particular runoff losses, the program offers the possibility of running the operation modes C*utback flow* and *Tailwater reuse.* The program does not compute how the runoff water reenters the system, which is controlled by local conditions. In the *Tailwater reuse* mode, a certain fraction of the runoff water specified by the user is assumed to be reused within the same border. In the *Cutback* mode, the assumption is that when water reaches the end of the border strip, the inflow is reduced to a value less than the inflow rate during the advance phase. The flow rate is constant before and after cutback.

The applicability of the BORDEV program is therefore bound by conditions that satisfy the assumptions stated above. Nevertheless, the simulation results with BORDEV will be in line with field observations, provided that the field conditions match the above-mentioned practical assumptions. As stated in the other programs, the BORDEV program only deals with the technical

and hydraulic aspects of border irrigation. The program should therefore be regarded as an aid in the design, operation and evaluation. Final decisions in the field will be controlled findings of the program in conjunction with agricultural, economic and social considerations.

6.6 Program usage

The following nine steps are important in the usage of the BORDEV program.

1. Start the SURDEV package. Select BORDEV from the main menu of SURDEV.
2. If you want to use an existing file, retrieve it with the *Load* command under the *Files* menu. If you want to make a completely new file, go straight to the *Calculation menu*, bypassing the *Files* menu and you will get a set of default data.
3. If you want to simulate cutback flow or reuse, go to the *Operation menu* and select the operation mode to work with. The program default operation mode is Fixed Inflow.
4. Select the *Units* menu only when you want to work with units other than the default units.
5. The default infiltration mode is the Modified SCS Families. If you prefer to work with another infiltration mode, go to the *Infiltration* menu.
6. Select a mode from the *Calculation* menu. Most work will be done in Modes 3 and/or 4. Less experienced users can start in Mode 1 or 2 to get a first estimate of the flow rate or field dimensions, respectively. Mode 4 can be used to evaluate existing situations or to do sensitivity analyses.
7. In the input window, Field parameters and Decision variables can be specified, after which the program can be run with [F2].
8. You can view the results of each run in tabular form in the output window, or in graphical form using [F3]. The results of one simulation run (output and input in one file) can be saved in a separate file or can be appended to earlier runs in an existing file with [F4].
9. Select *Files* and *View / Print* from the main menu to see what has been done and/or to print a file directly, or convert it to a print file for a word-processor program, or convert it to a file to be imported in a spreadsheet program where you can make your own graphs.

6.7 Sample problems

In most cases, the user will not be satisfied with a solution obtained after one run, and will usually do a number of runs to get an acceptable solution. Two simple examples are given to illustrate this procedure. For more elaborate problems, see Chapter 8, Section 2.

6.7.1 Fixed flow system

An operation practice is to be developed for a fixed-flow border irrigation system. The field in which the system is to be installed is 450 m long in the direction of the main slope. The individual borders are 20 m wide. The soil is silty loam and can be classified by the intake family # 0.5. The net irrigation requirement is 100 mm. Other input values are default. The flow rate is to be determined in such a way that the application efficiency is at least 70 per cent and the cutoff time has a practical value.

1. We want to make a new file, and therefore do not need to use the *Files* submenu. Note, the operation, units and parameter modes and values to be used in this example are the default ones, so we can go directly to the *Calculation* menu and select *Mode 1: Flow Rate*. Enter the above values in the two input windows and make a run.
2. The results of this run (Table 6.5, Run 1) show that at a rate of 47 l/s, a border of 450 m long and 20 m wide can be irrigated with an application efficiency of 66 per cent. The corresponding uniformity coefficient is 91 per cent and the distribution uniformity is 78 per cent. This application efficiency is too low. Increase the flow rate to 50 l/s and run BORDEV in Mode 3 and observe the effect.
3. This run (Table 6.5, Run 2) reveals the application efficiency to be the same as before, which is still below the target efficiency. The cutoff time decreased from 485 to 457 minutes, but is still an impractical value. Next we make a run in Mode 4 to see the effect when the cutoff time is reduced from 457 to 420 minutes (7 hours);
4. With this run (Table 6.5, Run 3) the reduced cutoff time results in an application efficiency of 71 per cent, which is acceptable. The corresponding uniformity coefficient is 91 per cent and the distribution uniformity is 78 per cent. But, the consequence of reducing the cutoff time is also a slight under-irrigation: the minimum infiltrated depth is now 92 mm instead of 100 mm. Over the lower 56 m of the border, the average depth infiltrated would be 4 mm less than that required. The upper 394 m of the border would receive an over-irrigation of 20 mm. These results are acceptable.

Table 6.5 can be made with BORDEV. The procedure is as follows. Save Run 1 with [F4] and prescribe a particular file name (EXAMPLE1). BORDEV automatically adds the extension .BDR to this file name. Save Runs 2 and 3 with [F4] under the same file name using the *Append* option. Go back to the main menu, go to *Files* menu, select *Print*/View, then EXAMPLE1. See the results and select [F5] (*Print*/*Save*) and then the option *Text file*. BORDEV now automatically adds the extension .TXT to the file name EXAMPLE1. If you now go out of BORDEV, you can load the results in a word-processing program by retrieving the file EXAMPLE1.TXT. This is how you make Table 6.5.

Table 6.5 Bordev program for sloping border irrigation (Filename: EXAMPLE1)

Run no.		1	2	3
Type of system		1	1	1
Calculation Mode		1	3	4
Input Parameters	Units			
Flow rate	l/s	–	50	50
Length	m	450	450	450
Width	m	20	20	20
Cutoff time	min	–	–	420
Required depth	mm	100	100	100
Flow resistance	–	0.15	0.15	0.15
Bed slope	m/m	0.008	0.008	0.008
Intake family	–	0.5	0.5	0.5
Output Parameters				
Flow rate	l/s	47.02	–	–
Cutoff time	min	485	457	–
Application eff.	%	66	66	71
Storage eff.	%	100	100	99
Uniform. coeff.	%	91	92	91
Distrib. unif.	%	78	80	78
Deep perc. ratio	%	19	16	13
Runoff ratio	%	15	18	16
Avg. inf. depth	mm	128	125	117
Max. inf. Depth	mm	142	137	129
Min. inf. depth	mm	100	100	92
Surface runoff	mm	23	28	23
Over-irrigation	mm	28	25	20
Under-irrigation	mm	0	0	4
Over-irr. Length	m	450	450	394
Under-irr. Length	m	0	0	56
Advance time	min	287	260	260
Depletion time	min	542	514	476
Recession time	min	627	599	560
Opportunity time	min	339	339	300

The above problem concerned the *Fixed flow* operation mode. For the same situation as described above, BORDEV will now be used in the design of a *Cutback flow* operation mode.

6.7.2 Cutback flow system

This sample problem is presented to illustrate how the irrigation performance under the fixed flow system of Section 6.7.1 can be improved by switching to the cutback flow system.

1. Go to the *Operations* menu and select *Cutback flow.* Go to the *Calculation* menu and select Mode 1*: Flow rate*. Enter the same values in the two input windows as in Table 6.5 and make a run. Keep the default Advance Ratio at 0.33 and the default Cutback Ratio at 0.65.
2. The results of this run (Table 6.6, Run 1) show that at a flow rate of 69 l/s, a border 450 m long and 20 m wide can be irrigated with an application efficiency of 73 per cent. Once the water has reached the end of the border, the flow rate is reduced to 45 l/s. A cutoff time of 366 minutes is required.

Table 6.6 Bordev program for sloping border irrigation (Filename: EXAMPLE2)

Run no.		1	2	3
Type of system		2	2	2
Calculation Mode		1	3	4
Input Parameters	**Units**			
Flow rate	l/s	–	70	70
Length	m	450	450	450
Width	m	20	20	20
Cutoff time	min	–	–	300
Advance ratio	–	0.33	–	–
Cutback ratio	–	0.65	0.65	0.65
Required depth	mm	100	100	100
Flow resistance	–	0.15	0.15	0.15
Bed slope	m/m	0.008	0.008	0.008
Intake family	–	0.5	0.5	0.5
Output Parameters				
Flow rate	l/s	69.1	–	–
Cutback flow	l/s	44.92	45.5	45.5
Cutoff time	min	366	364	–
Cutback time	min	167	164	164
Advance ratio	–	–	0.45	0.55
Application eff.	%	73	73	82
Storage eff.	%	100	100	97
Uniformity coeff.	%	95	95	94
Distrib. unif.	%	88	89	86
Deep perc. ratio	%	13	13	4
Runoff ratio	%	14	14	13
Avg. inf. Depth	mm	113	113	99
Max. inf. depth	mm	119	119	106
Min. inf. depth	mm	100	100	86
Surface runoff	mm	23	24	18
Over-irrigation	mm	13	13	4
Under-irrigation	mm	0	0	6
Over-irr. Length	m	450	450	244
Under-irr. Length	m	0	0	206
Advance time	min	167	164	164
Depletion time	min	425	422	358
Recession time	min	506	504	437
Opportunity time	min	339	339	272

The corresponding uniformity coefficient is 95 per cent and the distribution uniformity 88 per cent. We run BORDEV in Mode 3 to see the effect when the flow rate is increased to a practical value of 70 l/s.

3. The outcome of this run (Table 6.6, Run 2) show that the application efficiency and the cutoff time remain practically the same (because of the slight difference in flow rate). The cutoff time, however, has an impractical value. Now go to Mode 4 to see the effect when this is reduced from 364 to 300 minutes.
4. This run (Table 6.6, Run 3) shows hat this reduction in cutoff time results in an application efficiency of 82 per cent. The corresponding uniformity coefficient is 94 per cent and the distribution uniformity is 86 per cent. Obviously, the reduced cutoff time also results in some under-irrigation: the minimum infiltrated depth is now 86 mm instead of 100 mm. Over the lower 206 m of the border, the average depth infiltrated would be 6 mm less than that required. The upper 244 m of the border would receive an over-irrigation of 4 mm. These results are acceptable.

A comparison of Tables 6.5 and 6.6 shows that a cutback flow operation mode can increase the application efficiency from 71 to 82 per cent, which is a considerable improvement.

Table 6.6 was also made with BORDEV. Once you are familiar with the foregoing basic elements of working with BORDEV, you can do more elaborate work, examples of which are presented in Chapter 8. These concern several sets of runs with which various relationships can be established. This not only illustrates the potential of the program, but also provides a deeper insight into the complex nature of the border irrigation process.